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Final Report

Project Title: Ecological Evaluation of Sedge Island Marine Conservation Area in Barnegat Bay

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Executive Summary

Conservation zones are important for maintaining the sustainability of ecosystems and populations of economically important species. In the third year of a three year study, the relative ecological value of the Sedge Island Marine Conservation Zone (SIMCZ) in Barnegat Bay, NJ was again assessed by comparing species diversity and abundance of fish and selected decapod crustaceans in three habitats (seagrass, algae, and unvegetated) inside the SIMCZ with an area outside the conservation zone. Long-term data sets are required to adequately assess the ecological value of conservation zones, thus, NJ-DEP staff and volunteers were trained in the field techniques to insure continued data collection in the future. Finally, based on results from previous years, the relative importance of the SIMCZ as a refuge against fishing pressure for adult blue crabs was tested using tag-recapture techniques. As in previous years, cylinder (i.e., throw trap) sampling indicates that species diversity, the total abundance of organisms and the abundance of juvenile blue crabs were similar inside the SIMCZ as compared to outside the SIMCZ. The few differences in abundance between the SIMCZ and outside the conservation zone may be attributed in part to relative proximity to the inlet. Habitat was far more important than location in accounting for the differences in species diversity and total abundance of organisms. In general, vegetated habitats (SAV and algae) contained more species, total organisms and several individual species than unvegetated areas. Evidence suggests that the SIMCZ contains habitats that are ecologically valuable and are helping to sustain valuable species. Finally, tagged crabs in the SIMCZ exhibited recapture rates higher than expected and days-at-large times shorter than expected suggesting the recreational fishing effort inside the SIMCZ may be higher than a comparable area with very little recreational (or commercial) fishing. Thus it may be prudent to collect information on recreational fishing activities occurring in the SIMCZ.

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Introduction & Problem Statement

Marine protected areas (MPAs), no-take zones or marine reserves, where harvesting is banned or limited to some degree, have become an increasingly used strategy for conserving economically important species (Edgar et al. 2014). MPAs have been established world-wide and their effects on species assemblages and/or diversity (Bell 1983, Lipej et al. 2003, Holland and Schnier 2006, Barrett et al. 2009), fisheries productivity (Roberts et al. 2001, Gell and Roberts 2003, Alcala et al. 2005, Goni et al. 2006, Hart 2006), and population characteristics of a variety of fish (Macpherson et al. 2000, Le Port et al. 2012), and invertebrates (Branch and Odendaal 2003, Barrett et al. 2009, Leite et al. 2009, Jack and Wing 2010) have been well studied. Assessing the influence of MPAs on particular species often involves comparisons of population characteristics or life history traits of organisms inside an MPA with that outside the MPA. One criticism of that technique is that areas outside the MPA may vary in habitat type or quality (Curley et al. 2013), particularly if the MPA is designed to protect habitats that are essential for some aspect of an organism's life history, such as spawning (Golbuu and Friedlander 2011). Therefore, it is important for empirical studies that seek to assess the importance of MPAs by comparing them with areas outside the realm of protection to control for factors, other than the lack of fishing, which may influence the variables being measured.

The Sedge Island Wildlife Management Area in Barnegat Bay is located within New Jersey's first Marine Conservation Zone, just off Island Beach State Park. New Jersey's Wildlife Management Area System is administered by the Division of Fish and Wildlife's Bureau of Land Management for preserving a diversity of habitats for fish and wildlife, particularly economically important species. Indeed, in the two year ecological evaluation study previously funded by NJ-DEP, the juveniles of summer flounder, winter flounder and blue crabs were common in the Sedge Island Marine Conservation Zone (SIMCZ). That study also showed important annual variation in the abundance of juvenile blue crabs suggesting the potential value of long-term monitoring of key species in the SIMCZ for population managers and as an indicator of the health of the Barnegat Bay ecosystem. Finally, results from the previous study suggest that the SIMCZ may be an important refuge from fishing pressure for adult blue crabs but a more systematic test of that idea is necessary. Therefore, in this third year of funding, my goals were the following: (1) capture annual variation in the abundance and diversity of organisms in three key habitats inside and outside the SIMCZ; (2) train NJ-DEP volunteers and/or staff as an initial step towards establishing a long-term monitoring program in the SIMCZ; and (3) test the value of the SIMCZ as a refuge against fishing pressure for adult blue crabs.

Project Design & Methods

In year three, I proposed to continue to assess the ecological value of the SIMCZ by comparing the following biotic aspects inside the SIMCZ with an area outside the conservation zone; species diversity and abundance of fish and selected decapods (including blue crabs) in three shallow-water habitats (seagrass, macroalgae and unvegetated). During this work, NJ-DEP volunteers and/or staff were trained in the field techniques. Finally, using tag-recapture techniques, I compared recapture rates and number of days-at-large between adult crabs tagged and released in the SIMCZ with tagged crabs released in similar areas lacking fishery protection.

Sampling Techniques: Tag-Recapture

Results from years 1 and 2 suggest that the SIMCZ may be an important refuge from fishing pressure for adult blue crabs. In year 3, tag-recapture techniques were used to systematically test this idea. Three physically similar, semi-enclosed bays were chosen that varied in the extent of commercial and recreational fishing pressure: SIMCZ (commercial-none, recreational-present but at an uncertain level), Turtle Cove (commercial-low, recreational-low), and Tuckerton Creek (commercial-low, recreational-high) (Figure 1). At each location, monthly (June-August) tagging of adult, legal-sized blue crabs (>117 mm carapace width) captured within the location occurred. Floy tags were attached to the carapace of each crab using stainless steel wire (Figure 2). While the monthly number of tagged crabs varied somewhat among the locations, a total of 462 tagged crabs at each location was released over the entire summer. Information from recreational captors of tagged crabs allowed the computation of a recapture percentage (number of tagged crabs recaptured/the total number released) and the number of days-at-large (date recaptured-date released). Recapture percentages were compared among the locations using χ^2 analysis (with an equal distribution of recapture rates as the expected values) and days-at-large were compared among locations via one-way ANOVA.

Training NJ-DEP Staff and Volunteers

The objective was to show NJ-DEP staff and volunteers the sampling techniques for assessing species diversity and the abundance of fish and selected decapods using sampling cylinders (i.e., throw traps) so that the NJ-DEP may establish a long-term sampling program to assess the ecological importance of the SIMCZ. This was accomplished simply by inviting NJ-DEP staff and volunteers to participate in field sampling so that they could experience it first-hand.

Sampling Techniques: Species Diversity and Abundance of Fish and Selected Decapods

The objective was to examine the temporal and spatial variation in the species diversity and abundance of fish and selected decapod crustaceans among three common estuarine habitats existing inside and outside the SIMCZ. Sampling was performed using quantitative samplers (i.e., cylinders) deployed daily for four consecutive days during each month (May-August 2016). Sampling was performed in two locations: inside the SIMCZ and outside the SIMCZ. Each location contained four replicate sampling sites with each site containing the three habitats: seagrass, macroalgae, and unvegetated (Figure 3). Each sampling day, one of the sampling sites in each location was chosen at random and two cylinder sets were performed in each habitat. Each sample from the seagrass and unvegetated habitats contained 100% coverage of the respective habitat. However, the samples from the algae habitats systematically varied in the extent of percent coverage of algae; one sample contained at least 75% coverage ("high") while the other sample contained no more than 25% coverage ("low"). This provided the opportunity to test the importance of the amount of algae on species diversity and the abundance of fish and selected decapods. Cylinders were circular (1.12m diameter x 0.84m tall) and enclosed a $1.0m^2$ area. Long-handled dip nets with fine mesh were used to sweep the benthos (and nekton) enclosed by the cylinder. Sweeps ended when nothing was captured after five successive sweeps. The catch was processed in the field: fish and shrimp were identified to species and total length (of 21 individuals) was measured; crabs were measured for carapace width, sex, age-class, sexual maturity, molt stage, limb loss and regeneration, and ovigerous stage (adult females). Physical characteristics including depth, salinity, temperature, and dissolved oxygen were taken with a hand-held YSI data logger (model 6920) at each cylinder set. Depth was also measured with a depth pole marked at 10cm increments and verified using the YSI. The time and tidal stage were also noted. Dependent variables (e.g., number of species, total abundance and abundance of selected species) were analyzed using a three-way ANOVA with month, location and habitat as independent variables. To test the importance of the amount of algae on species diversity and the abundance of fish and selected decapods, a separate three-way ANOVA with month, location, and algal coverage (high vs low) was performed within the algae habitat.

Quality Assurance

The YSI 6920 handheld data logger, which records temperature, salinity, and dissolved oxygen, is calibrated before and after each field sampling. All water quality testing is performed by a New Jersey laboratory certified person under the requirements of N.J.A.C. 7:18 or laboratories which have formal approval from the NJDEP-Office of Quality Assurance. Certificates of formal approval are specific to the QAPP related analytical testing and are effective until June 30th of every year.

Results & Discussion

Tag-Recapture

Monthly (June-August) tagging occurred at each of three locations that varied in the extent of commercial and recreational fishing pressure: SIMCZ (no commercial, recreational present but at an uncertain level), Turtle Cove (low commercial, low recreational), and Tuckerton Creek (low commercial, high recreational). These locations were all semi-enclosed bays with similar physical characteristics (Figure 4). A total of 462 adult crabs were tagged at each location throughout the summer. As expected based on the difference in the level of fishing pressure, the recapture rate at Tuckerton Creek was significantly higher than Turtle Cove (χ^2, P=0.022) and it was greater than the SIMCZ, but the difference was not statistically significant (Figure 5). Surprisingly, the recapture rate at SIMCZ was also greater than Turtle Cove but the difference was not statistically significant. The days-at-large of tagged crabs varied significantly by location ($F_{2,78}$=3.63, P=0.031). As expected, tagged crabs were at-large significantly longer at Turtle Cove than the SIMCZ (Tukey P=0.024) and longer than Tuckerton Creek but that difference was not statistically significant (Figure 6). The time-at-large in the SIMCZ was quite short and this could be due to tagged crabs being particularly vulnerable to recreational fishermen in the SIMCZ who, unlike recreational fishermen who use traps, simply look for crabs in shallow water and capture them using a dip net. Thus, crabs with a brightly colored tag affixed to them are very easily spotted. Taken together, these results suggest that the recreational fishing effort at the SIMCZ is somewhat higher than expected being somewhere between Turtle Cove (low rates of recreational and commercial fishing) and Tuckerton Creek (high rate of recreational and low rate of commercial). In support of the relative importance of recreational fishing on the recapture results, it is interesting to note that the highest incidence of recaptures at each location was during July or August, at the height of the summer season (Figure 7).

Training NJ-DEP Staff and Volunteers

During the summer, several NJ-DEP and Sedge Island staff members as well as volunteers participated in field sampling. In this report, I have included samples of the field data sheets used during sampling. What follows is a compilation of the field protocols.

Cylinder sampling takes place on 4 successive days per month (May-August) both outside and inside the SIMCZ on each day and this process takes approximately 8 hours. Cylinder sampling must be done in a 2-3 hour window before and after low tide in water depths of less than 0.80 meters in order to prevent overwash of the cylinders. Therefore, it is best to sample on days when low tide occurs in the morning. The timing of low tides can be obtained at the salt water tides website (http://www.saltwatertides.com/). Low tides for the area outside the SIMCZ (High Bar Station) occur approximately 2 hours prior to low tides inside the SIMCZ (Island Beach, Sedge Islands Station), thus it is easier to accomplish sampling at both locations by starting outside the SIMCZ. While established sampling sites containing specific habitats (SAV, algae, open) exist, it is very helpful to be able to visually inspect the sites prior to deploying the cylinder (especially the algae habitats), therefore sampling in turbid conditions (due to windy and/or rainy conditions immediately prior to or during sampling) is very difficult and should be avoided. Many of the sites will be in shallow water, therefore a shallow draft boat with an engine that can be hydraulically lifted will make getting to sampling sites much easier.

At both sampling locations (outside and inside SIMCZ), there are at least 4 sampling sites per habitat (SAV, algae, open), thus a different site should be used each sampling day. At each habitat, two replicate samples are taken. Depending on the size of the crew, this can be accomplished simultaneously using two cylinders at either end of the boat, or sequentially by deploying one cylinder at a time (Figure 8). Before deploying the cylinders, the boat needs to be "set" to facilitate sampling. The optimal positioning is accomplished by setting two anchors to windward at either end of the boat (Figure 8). Once the anchors have "caught", the boat remains relatively stable and cylinders should be deployed to leeward. Thus, the boat protects the cylinders from wind and waves so the cylinders remain stable during sampling.

Deploying the cylinders requires two people because they are cumbersome and weigh ~40 pounds. The cylinders should have a line around the outside that is fed through the handles and then tied to itself (Figure 9). To deploy the cylinder, crew members can lift the cylinder to the edge of the boat, then the cylinder can be hung over the side by holding onto the line and dropped onto the habitat. The line can also be used to lift the cylinder out of the water and back onto the boat. During sampling, one member of the crew is already in the water, so he/she should help lift the cylinder back onto the boat from their position in the water. The cylinders can wedge themselves into the sediment during sampling and can be difficult to extract. Usually lifting with a rocking motion will release the cylinder but on rare occasions the cylinder must be extracted by tying it to the boat and pulling the cylinder out with the boat. Sampling the SAV and open habitats is fairly straightforward; both replicate samples in each of these habitats occurs where there is 100% cover of either SAV or sand with no vegetation, respectively so minimal visual inspection of the sampling site is needed to verify the 100% cover of the habitat type. Sampling the algae habitat is more challenging because the two samples of algae vary in the extent of vegetative cover (one $\leq$ 25% cover; the other $\geq$ 75% cover), so more visual inspection is required to locate areas that vary in algae cover. Indeed, the cylinders may need to be deployed in slightly different locations and thus require the boat to be set twice to accomplish that. Sampling in algae often requires one member of the crew to get in the water to physically position the boat in order to deploy the cylinders in the correct location.

Once the cylinder is deployed, data collection can begin. Physical data (see sample physicals data sheet) are taken first before the area inside the cylinder is disturbed by sampling. Estimates of percent cover of vegetation should also be done prior to sampling (see sample cylinder sampling-fish and shrimp data sheet). Sampling for organisms is done by sweeping along the benthos throughout the cylinder with a long-handled dip net. It is important to sweep along the insider perimeter of the cylinder (where organisms try to hide) as well as through the middle. Sweeping should also occur periodically throughout the water column inside the cylinder as well in order to capture any nektonic organisms. The net must be pressed against the bottom enough to capture benthic organisms but not dug into the sediment. The samples from each sweep can be deposited in shallow bins for the crew members to sort. Crew members should carefully visually inspect and even gently shake any vegetation in order to extract any crabs, fish or shrimp for sizing and counting. The vegetation should be saved in a bucket marked to measure the total volume of vegetation collected and to note those algae species that dominate the sample. Sweeping should continue until 5 empty (no crabs, shrimp or fish) sweeps in a row have occurred.

For fish and shrimp, up to 21 individuals of each species should be measured for size: total length for fish (snout to tail) and shrimp (rostrum to tail; see Figure 10) (see sample cylinder sampling-fish and shrimp data sheet); the rest should be counted. Crab data goes on a separate data sheet (see sample cylinder sampling-crabs data sheet). Before measuring crabs, you should estimate if there are more than 25 individuals for any species of crab. If so, then one side of a crab data sheet should be dedicated to each crab species with more than 25 individuals. If not, then crabs can be added to the data sheet in any order. For crabs, up to 25 individuals should be measured for carapace width (between tips of lateral spines for blue crabs or across the widest part of the carapace for other species; see Figure 10); the rest should be counted. Additional data for crabs includes sex, age, molt stage (pre- and post-molt for blue crabs; post-molt for all other species), limb loss, and ovigerous stage of adult females (see sample cylinder sampling-crabs data sheet). Pre-molt stages of blue crabs are shown in Figure 11 and ovigerous stages of blue crabs are shown in Figure 12. If only one cylinder is being sampled and the other will be deployed at the same spot, then animals being processed from the first cylinder should not be returned to the water but instead should be temporarily saved on board to prevent “seeding” the next cylinder sample with organisms. These animals can be returned once the second cylinder is deployed. Similarly, if both cylinders are deployed simultaneously, crew members must avoid returning processed animals back into the cylinders.

Species Diversity and Abundance of Fish and Selected Decapods

<u>*Species Diversity*</u>

The total number of species of fish (11) and decapods (12) captured in the SIMCZ was similar to the number of species of fish (12) and decapods (13) captured outside the SIMCZ (Table 1). Both inside and outside the SIMCZ, vegetated habitats (algae and SAV) contained a greater number of species (Table 1 and Figure 13) and had larger Shannon-Weiner Indexes (S-W) (Table 1) than the open habitat. In both locations, S-W values were higher in algae than in SAV and the S-W values in both vegetated habitats were higher outside the SIMCZ than inside the SIMCZ (Table 1). The differences between the locations is primarily due to the greater incidence of rare species being present outside the SIMCZ. The S-W index incorporates both species richness (number of species) and evenness (relative abundance of each species). Therefore, the indexes of the open habitats were relatively low compared to the structured habitats because while several species were captured in open habitats, only one (sand shrimp) numerically dominated open habitats (Table 1). S-W values in algae were higher than SAV both inside (especially) and outside the SIMCZ because algae contained both a greater number of species as well as a more uniform relative abundance of those species (Table 1). Higher S-W values occurred in algae versus SAV despite variability in the percent cover of algae versus consistently high percent cover in SAV. The percent cover of algae influenced the S-W values in both locations; S-W values were higher in high percent cover of algae (1.5, 1.7 inside and outside respectively) as compared to low percent cover (1.0, 1.3 inside and outside respectively). S-W values in algae (especially) and SAV were higher outside the SIMCZ as compared to inside because both habitats outside contained a greater number of species as well as a more uniform relative abundance of those species (Table 1).

The number of species was influenced by location ($F_{1,126}$=11.8, P=0.0008), month ($F_{2,126}$=8.8, P=0.0002) and habitat ($F_{2,126}$=150.8, P<0.0001), which accounted for most (65%) of the variation. On average, slightly but significantly more species were present outside (5.2 $\pm$ 2.3 SD) as compared to inside the SIMCZ (4.5 $\pm$ 2.0 SD), again mainly due to the greater incidence of rare species being present outside the SIMCZ. Overall, both algae (Tukey P<0.0001) and SAV (Tukey P<0.0001) contained more species than the open habitat, and this occurred in both locations (Figure 13). Species richness increased as the summer progressed; more species were present in August as compared to July (Tukey P=0.013) and June (Tukey P<0.0001) (Figure 14). In algae habitats, on average there was 1 more species present in high percent cover (6.8 $\pm$ 1.3 SD) as compared to low percent cover (5.8 $\pm$ 1.6 SD).

<u>*Abundance of Fish and Selected Decapods*</u>

Total abundance varied significantly among the habitats ($F_{2,126}$=47.8, P<0.0001), which accounted for 28% of the variation, but this spatial variation was influenced by month (month x habitat interaction; $F_{4,126}$=11.6, P<0.0001). In addition, monthly variation in total abundance was also influence by location (month x location interaction; $F_{2,126}$=8.2, P=0.0005). Indeed, total abundance was influenced by the three-way interaction between month, location and habitat ($F_{4,126}$=3.4, P=0.011) (Figure 15). A significant effect of location occurred only in August within the SAV habitat, where total abundance was greater outside the SIMCZ as compared to inside the SIMCZ (Figure 15). Some monthly variation in abundance occurred in both vegetated habitats outside the SIMCZ but none occurred inside the SIMCZ. Outside the SIMCZ, total abundance in SAV was greater in August than either July or June (both comparisons, P<0.05) whereas in algae, total abundance was greater in August and July as compared to June (both comparisons, P<0.05) (Figure 15). Differences in total abundance among the habitats occurred in both locations but those differences varied among the months. In July, total abundance was lower in open habitats compared to SAV inside the SIMCZ (Tukey P<0.05) but compared to algae outside (Tukey P<0.05) the SIMCZ (Figure 15). However, in August inside the SIMCZ, abundance in both vegetated habitats was similar and exceeded abundance in the open habitat (both comparisons, P<0.05) whereas outside the SIMCZ, abundance in SAV surpassed that in both algae and open habitats (both comparisons, P<0.05) (Figure 15). This sharp increase in abundance in SAV outside (double that of inside) may be due to the proximity of the outside location to Barnegat Inlet and thus increased access by individuals in planktonic stages recruiting to the estuary from offshore and/or subsequent recruitment by those individuals to juvenile stages. Many fish and invertebrates are known to use SAV for both of these ontogenetic shifts.

One way of testing the idea that abundance differences between the locations may be due to proximity to Barnegat Inlet is to compare abundance patterns of species that have similar habitat use patterns but differ in the extent of recruitment of early life history stages via Barnegat Inlet. For example, mud crabs and sticklebacks both prefer vegetated habitats (especially SAV) but while mud crab larvae develop offshore and subsequent early life history stages recruit to the estuary via Barnegat Inlet, stickleback larvae are produced within the adult habitat and are retained in the estuary. The abundance of sticklebacks ($F_{2,126}$=14.9, P<0.0001) and mud crabs ($F_{2,126}$=5.6, P=0.004) are influenced by the interaction between habitat and location but the abundance patterns contrast between locations. In SAV, sticklebacks are more abundant inside the SIMCZ whereas mud crabs are more abundant outside the SIMCZ (Figure 16) and this pattern was repeated in years 1 and 2.

The percent cover of algae had a significant effect on the abundance of those species that show clear preferences for vegetated habitats. For example, grass shrimp, sticklebacks and mud crabs are rarely found in open areas, however sand shrimp is the one species that is consistently found in open areas. The abundance of grass shrimp ($F_{1,36}$=4.2, P=0.04), sticklebacks ($F_{1,36}$=21.7, P<0.0001) and mud crabs ($F_{1,36}$=5.6, P=0.02) were significantly higher in high percent cover of algae while the abundance of sand shrimp ($F_{1,36}$=0.1, P=0.74) did not differ between levels of algal percent cover (Figure 17). Blue crabs, particularly juveniles, typically prefer vegetated habitats over open areas, however, blue crab abundance did not differ between levels of algal percent cover ($F_{1,36}$=0.03, P=0.84) (Figure 17). In fact, the abundance of blue crabs did not significantly vary based on any of the independent factors (month, location, habitat) or any of the interactions between these factors.

Conclusions and Recommendations for Future Research

The results of the tagging study suggest that the level of recreational fishing in the SIMCZ may be relatively high thus it may be prudent to get a better understanding of the numbers of recreational fishermen in the SIMCZ and their catch.

As in previous years, there were few differences in species diversity and abundance of fish and selected decapods between the SIMCZ and a similar area outside the conservation zone suggesting that the SIMCZ is providing habitats of similar quality for a variety of species. Based on the cylinder sampling, these species include the juveniles of commercially and recreationally important species such as blue crabs and winter flounder. Continuing the comparison of abundance, diversity of fish and selected decapods between the SIMCZ and at least one similar area outside over the long-term provides the opportunity to not only determine if the conservation zone creates unique conditions for estuarine organisms but also to determine if those potential conditions are changing overtime. Over the past three years, the field study has occurred only during the summer months. However, there would be advantages to conducting the study on a seasonal basis; for example to provide better opportunities to capture important biological events in the life history of estuarine organisms such as recruitment of early life history stages. Thus, rather than monthly sampling (May-August), seasonal sampling (e.g., May, July, September) would reduce the sampling effort but increase the chance of capturing recruitment of some important invertebrates (e.g., blue crabs) into the estuary. Another change to the sampling that would reduce effort without sacrificing too much information would be to process crabs the same way as fish and shrimp (i.e., size and abundance only). While information about molting, limb loss and ovigerous stage would be lost, processing time would decrease. I collect this information because of my particular interest in crabs but these data are not universally collected by other estuarine scientists doing similar types of studies.

Recommendations and Application and use by NJDEP

The tagging study provides an incentive to collect information on relative fishing effort, for blue crabs but also for other species, inside the SIMCZ. This is an important consideration because, the combination of designating the area as a conservation zone while allowing recreational fishing and providing land access to the area, could elevate the level of fishing inside the SIMCZ beyond other comparable areas (i.e., semi-enclosed, shallow water bays). Based on personal observation, many fishermen in the SIMCZ access the area via land (the Area 21 kayak launch). Those fishermen could be asked (at the park entrance kiosk) to complete a survey providing information that could be used to address the potential impacts of recreational fishing in the SIMCZ.

Overall, the results of the cylinder sampling suggest that the SIMCZ provides valuable habitats (of similar quality to a comparable area outside the conservation zone) to a variety of species including the economically valuable blue crab. Considering the lack of previous scientific inventory in the SIMCZ, the NJDEP now has quantitative validation for the historical designation of this area as a conservation zone and justification for this continued designation as well as future protection of the conservation zone. Continuing this sampling to accumulate a long-term data set comparing the SIMCZ with at least one area outside the SIMCZ is critical for assessing the ecological importance of the SIMCZ. This is especially true since, to my knowledge, there are no comparable data from the area prior to its designation as a conservation zone. Thus, it is not possible to examine the impact of the SIMCZ by comparing biotic aspects before versus after its designation as a conservation zone.

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Figures & Tables

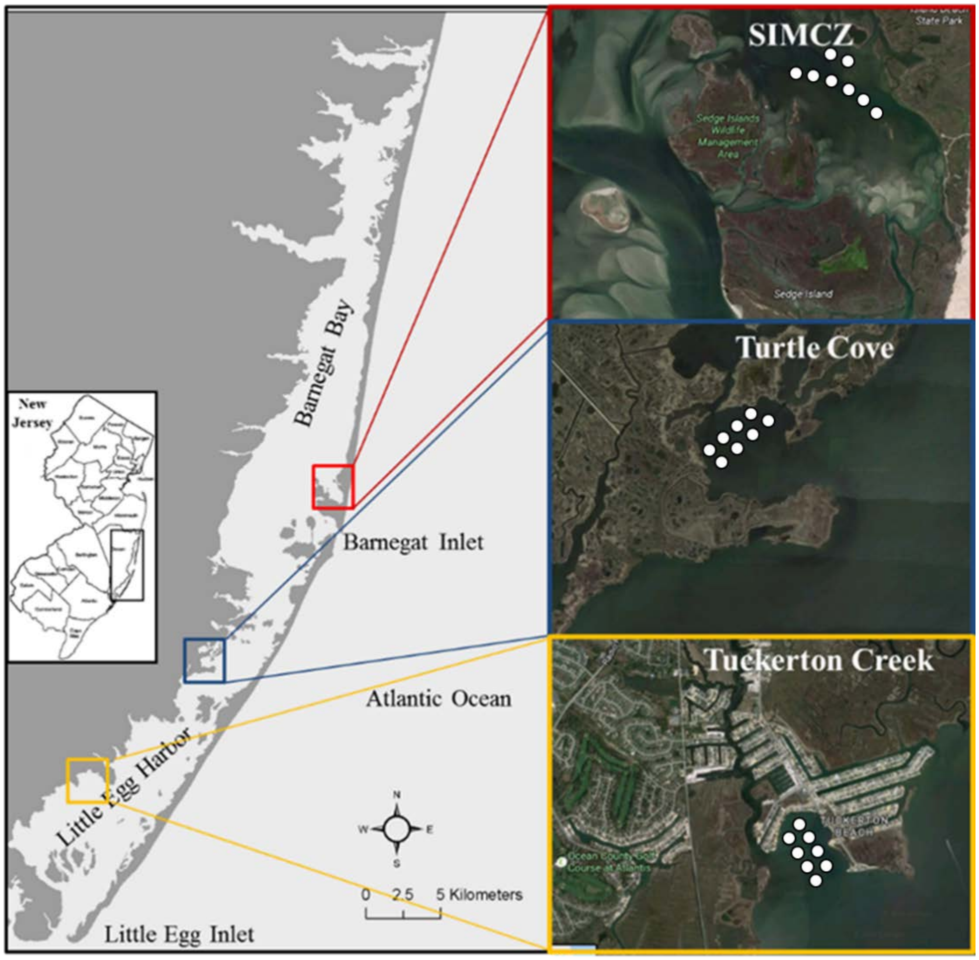

Figure 1. Map of tagging locations with approximate locations of sampling sites also shown.

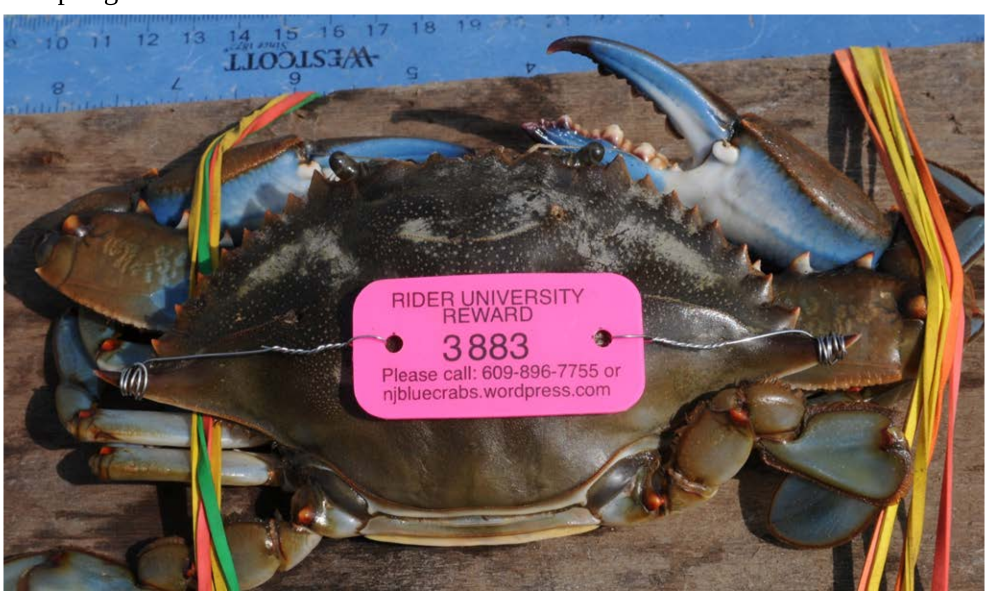

Figure 2. Tagged crab.

Figure 3. Approximate locations of cylinder sampling sites inside and outside the SIMCZ. s=SAV, a=Algae, o=Open.

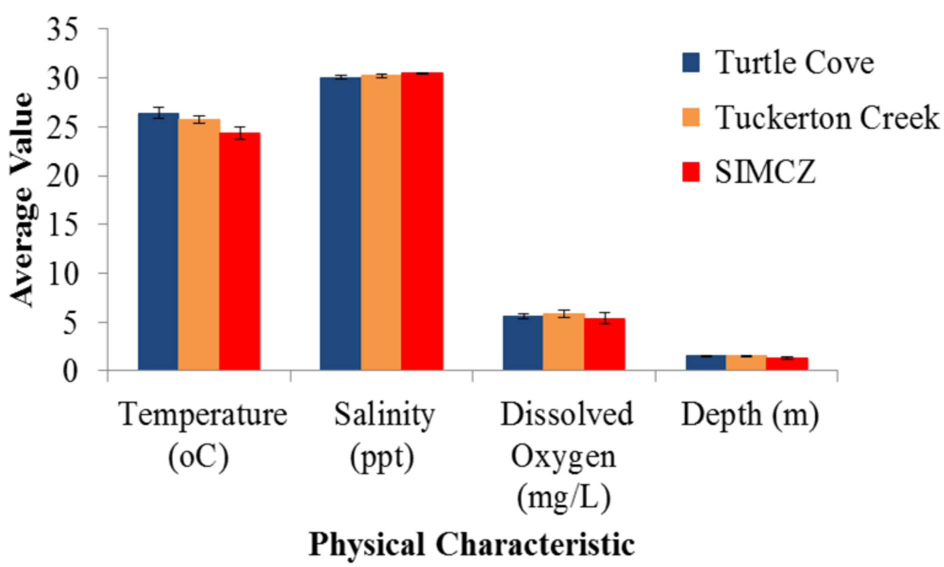

Figure 4. Mean (+ 1 SE) physical characteristics of the tagging locations.

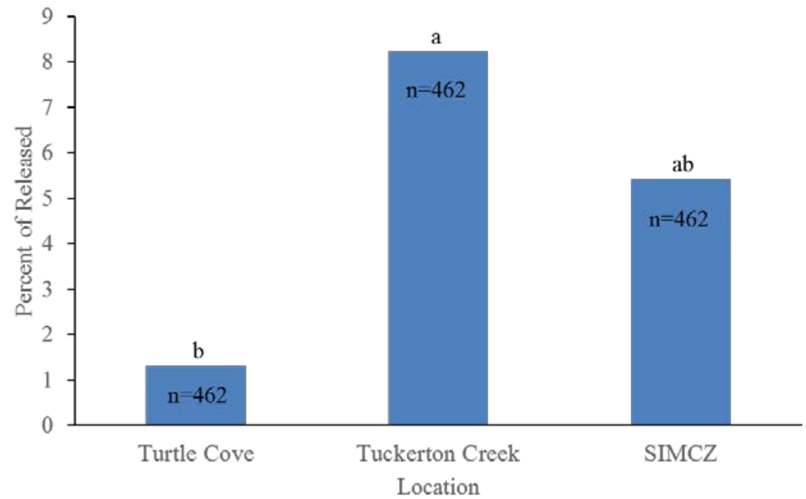

Figure 5. Percent of crabs recaptured at the three tagging locations. Sample size of tagged crabs is given for each location. Bars with different letters are significantly different (P<0.05).

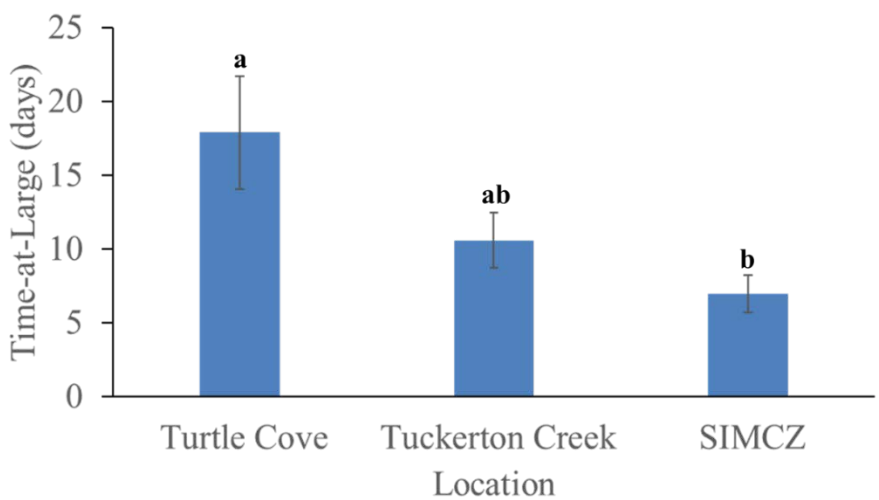

Figure 6. Mean (± 1 SE) time-at-large of recaptured crabs at the three tagging locations. Bars with different letters are significantly different (P<0.05).

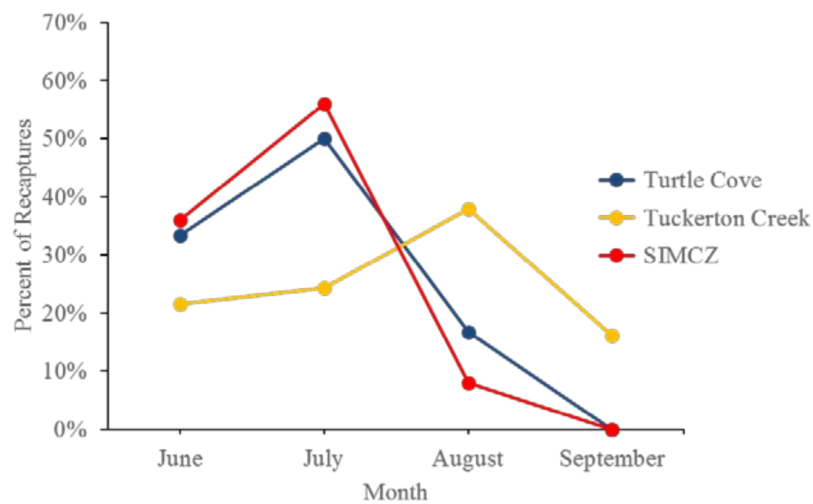

Figure 7. Monthly percentage of recaptures at the three tagging locations.

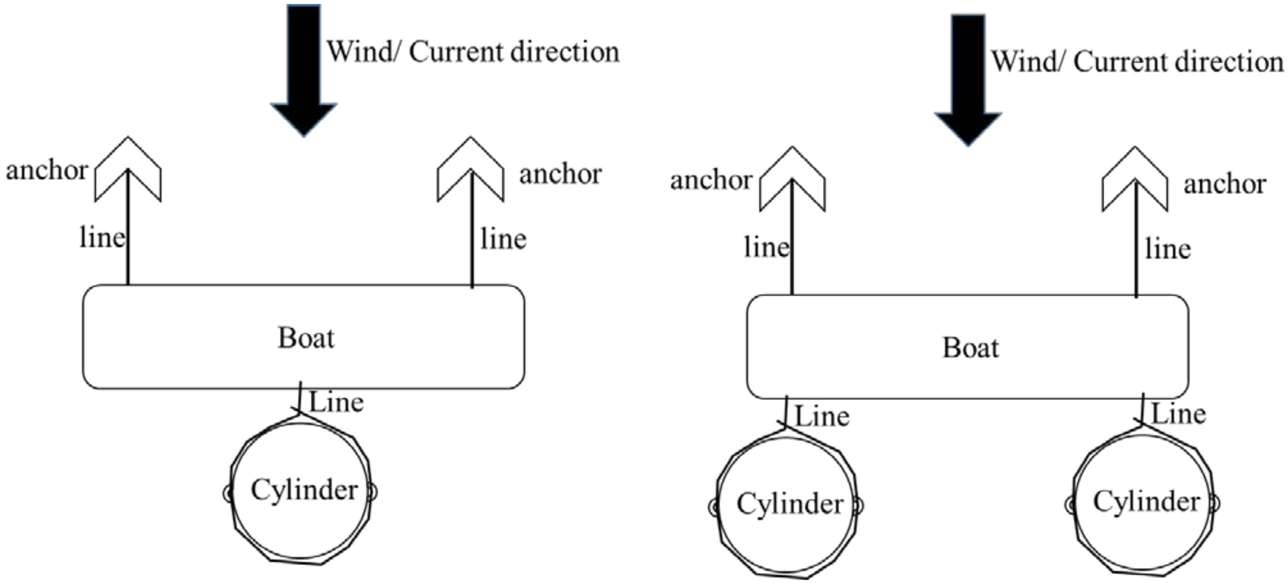

Figure 8. Diagram of cylinder sampling with one cylinder deployed (left) and two cylinders deployed simultaneously (right). Optimal position of boat relative to the wind is also shown.

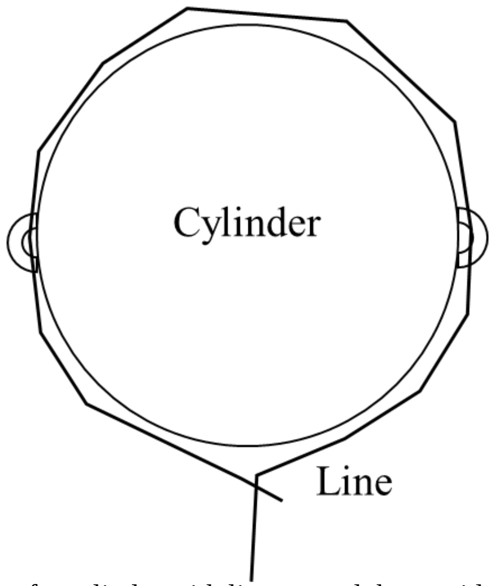

Figure 9. Diagram of a cylinder with line around the outside, fed through the handles.

Figure 10. Diagram of a total length measurement for shrimp and carapace width measurement for blue crabs (with lateral spines) and other crabs (without lateral spines). Black line indicates

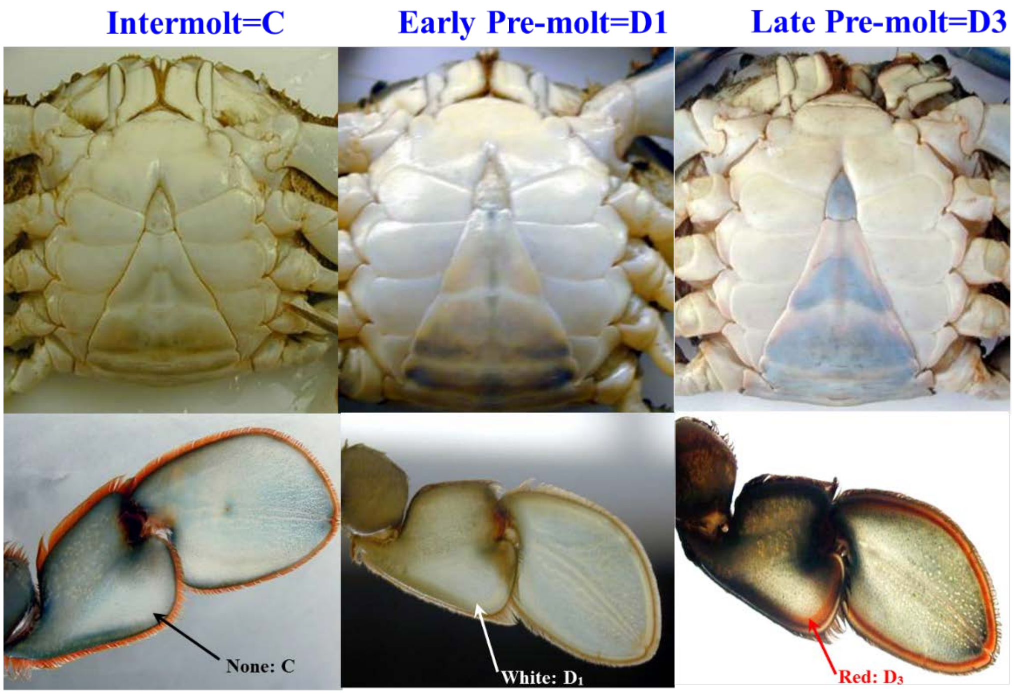

Figure 11. Images of pre-pubertal female blue crabs in three molt stages: C (left), D1 (middle) and D3 (right). Top panel shows characteristic color changes of abdominal flap. Bottom panel shows characteristic color changes on the second-to-last segment of the swimming paddle.

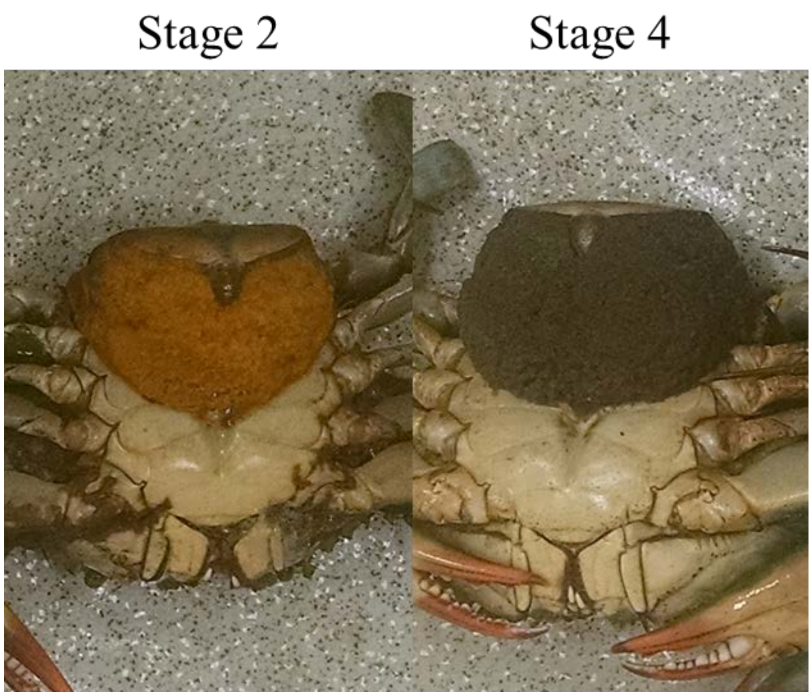

Figure 12. Images of blue crab ovigerous stage 2 (left) and stage 4 (right).

Table 1. Abundance of each species captured via cylinder in each habitat inside and outside of the SIMCZ, May-August 2016.

		Inside SIMCZ Habitat			**Outside SIMCZ Habitat**			
Common Name	**Species Name**	**open**	**algae**	**sav**	**open**	**algae**	**sav**	**Total**
Fish								
4-spine stickleback	*Apeltes quadracus*	7	505	2138	2	339	1094	4085
black sea bass	*Centropristis striata*		1				2	3
croaker	*Micropogonias undulates*						54	54
naked goby	*Gobiosoma bosc*		2		2	39	1	44
Northern kingfish	*Menticirrhus saxatilis*					1		1
Northern sea robin	*Prionotus carolinus*		1					1
oyster toadfish	*Opsanus tao*			2		3	1	6
pipefish	*Syngnathus fuscus*	2	11	4	1	14	9	41
rainwater killifish	*Lucania parva*			5		5	16	26
seahorse	*Hippocampus erectus*			1				1
silverside	*Menidia menidia*	183	52	116	25	113	91	580
summer flounder	*Paralichthys dentatus*						2	2
tautog	*Tautoga onitis*			1		3		4
winter flounder	*Pleuronectes aamericanus*	2	14	3	1	7	4	31
Decapods								
blue crab	*Callinectes sapidus*	2	42	23	5	257	33	362
grass shrimp	*Palaemonetes pugio*		105	190	1	273	300	869
green crab	*Carcinus maenas*		2	2			1	5
green shrimp	*Hippolyte sp.*			72		2	156	230
horseshoe crab	*Limulus polyphemus*	3	1			1		5
Japanese shore crab	*Hemigrapsus sanguineus*						1	1
lady crab	*Ovalipes ocellatus*	4	1		8	2		15
lesser blue crab	*Callinectes similis*	1	1			2		4
mud crab	*Neopanopeus sayii*	9	360	570	13	1165	1619	3736
pea crab	*Pinnixia sp.*		1			1		2
rock crab	*Cancer irroratus*	2	38	3	24	93	7	167
sand shrimp	*Crangon septemspinosa*	467	961	30	721	895	151	3225
spider crab	*Libinia emarginata*		1		2	6	1	10
Habitat Total		**682**	**2099**	**3160**	**805**	**3221**	**3543**	**13510**
Number of Species		**11**	**18**	**15**	**12**	**20**	**19**	**27**
Shannon-Weiner Index		**0.89**	**1.49**	**1.07**	**0.52**	**1.73**	**1.48**	

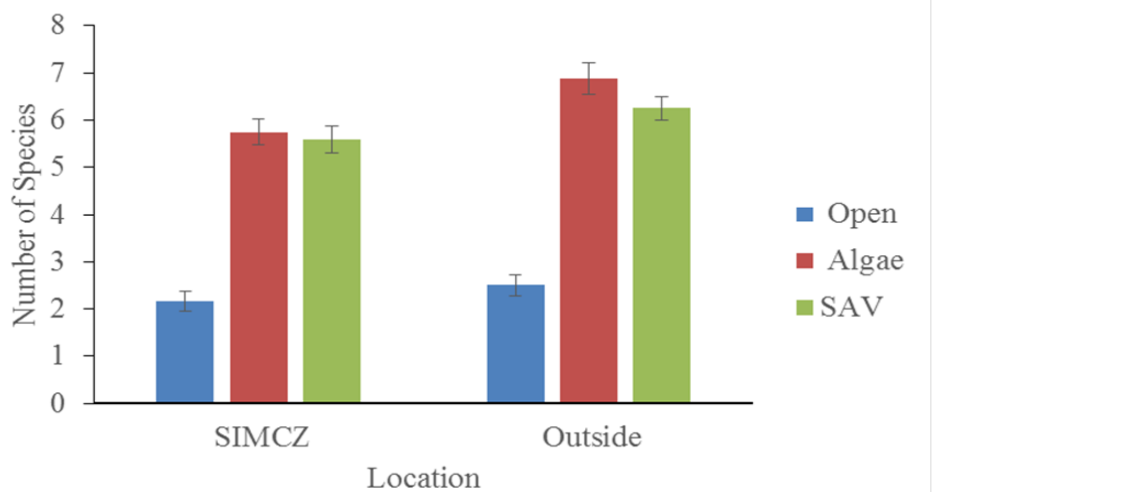

Figure 13. Average (± 1 SE) number of species in each habitat inside and outside the SIMCZ.

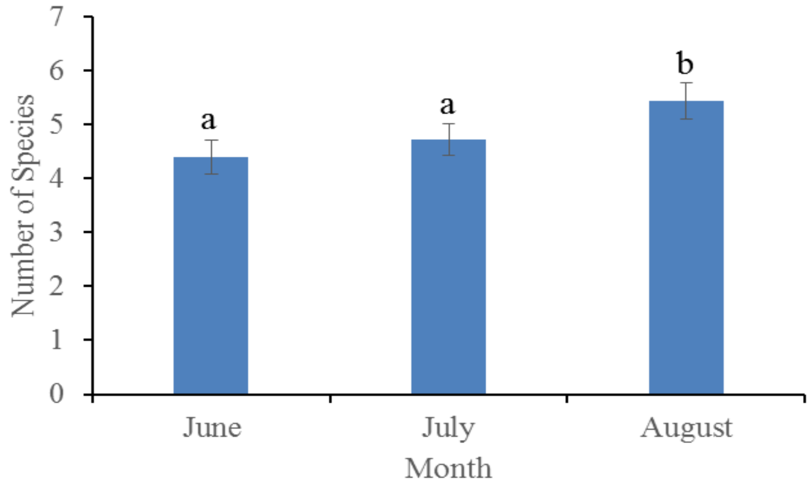

Figure 14. Average (± 1 SE) number of species in each month. Bars with different letters are significantly different (P<0.05).

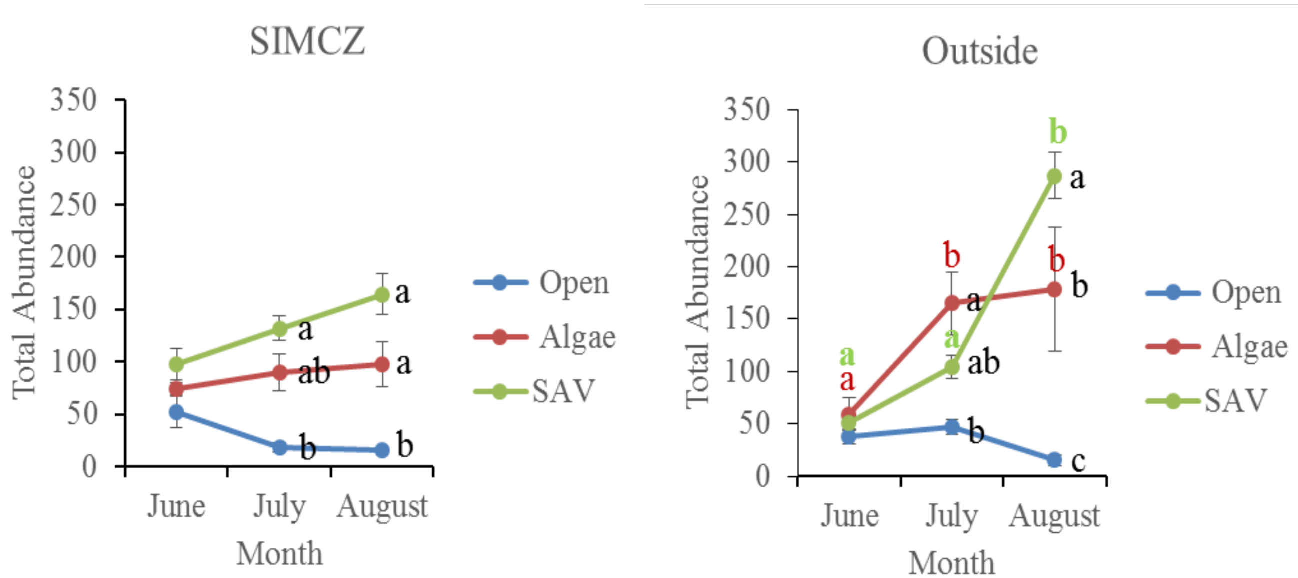

Figure 15. Average (± 1 SE) total abundance in each month in each habitat inside (left) and outside (right) the SIMCZ. Significant differences among habitats within months are designated by different black letters. Significant differences among months within habitats are designated with color-matched letters. Dots with different letters are significantly different (P<0.05).

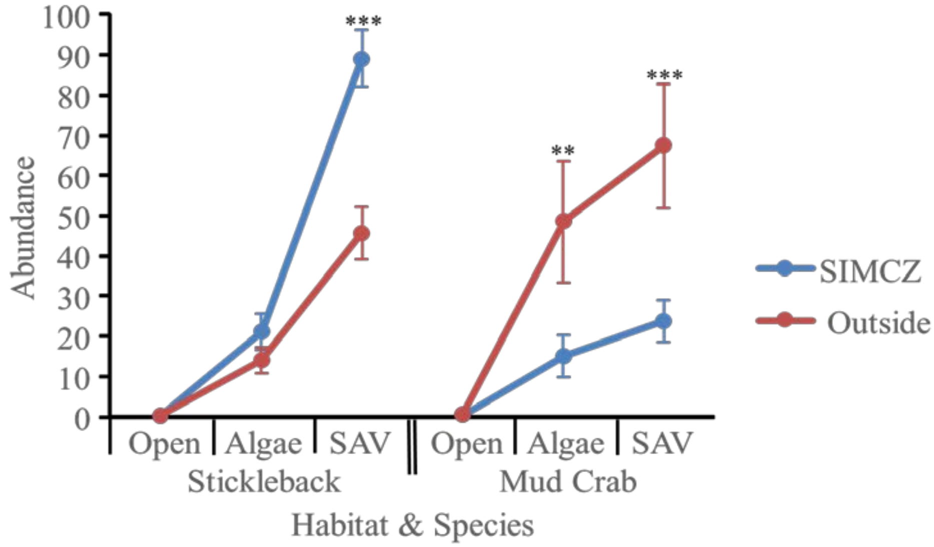

Figure 16. Average (+ 1 SE) of sticklebacks and mud crabs in each habitat in both locations. Asterisks above dots indicate significant differences between locations within a habitat for each species (**P<0.005, ***P<0.0001).

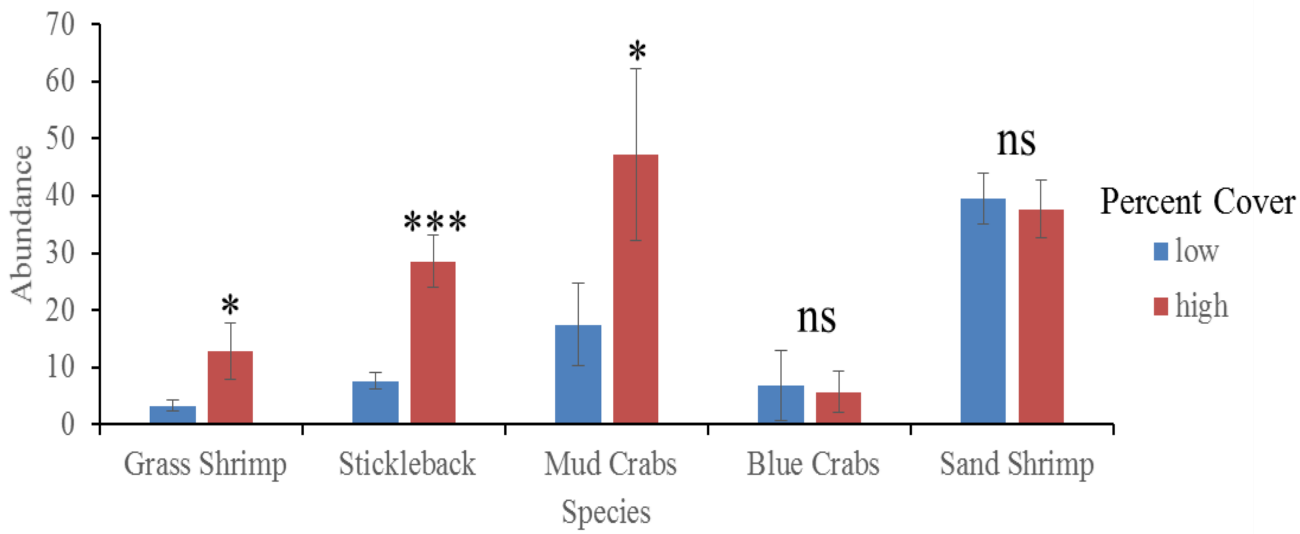

Figure 17. Average (+ 1 SE) of selected species each algae habitats differing in the extent of percent cover. Asterisks above bars indicate significant differences between percent cover levels within a species (*P<0.05, ***P<0.0001).

Sample Field Data Sheets: Cylinder Sampling-Fish and Shrimp

Your Initials ________ **2016-Sedge Island CYLINDER SAMPLING** Date ________

Site#	Circle Approriate Habitat	SAV	Algae	Open
Sample#	Circle Location	Inside	Outside	

	Total Length in mm of at least 21 individuals...then COUNT the rest						
Species							
Count of THE REST							

	Total Length in mm of at least 21 individuals...then COUNT the rest						
Species							
Count of THE REST							

	Total Length in mm of at least 21 individuals...then COUNT the rest						
Species							
Count of THE REST							

	Total Length in mm of at least 21 individuals...then COUNT the rest						
Species							
Count of THE REST							

	Total Length in mm of at least 21 individuals...then COUNT the rest						
Species							
Count of THE REST							

	Total Length in mm of at least 21 individuals...then COUNT the rest						
Species							
Count of THE REST							

% VEG COVER______

SAV% ________

ALGAE% ______

SPECIES/TYPES:

VEG VOL ________

Entered By ________

Checked By ________

Sample Field Data Sheets: Cylinder Sampling-Crabs

SIMCZ CYLINDERS **BLUE CRABS-2016** Your initials= page #=

Entered By=

Checked By=

Pre-Molt		Post-Molt	
color	molt	hardness	molt
none	C	fully hard	C
thin, red	D0	soft	A
white	D1	leathery	B1
orange-pink	D2	brittle	B2
pink-red	D3	barely gives	B3

0=None
1=yellow/pale orange + maybe mushy
2=orange
3=brown
4=black
5=remnants...egg membranes only

PROCESS 25 OF EACH SPECIES THEN COUNT THE REST

			Open	1				A			1=intact								
		OUT	Algae	2	1	CS	M	J			KIL2		Y	Y		BROOD MEASURES			
	6-Jun-09	IN	SAV	3	2	LE	F	P	in mm		-		N	N		mm	mm	mm	barnacle
	Date	**Locate**	**Habitat**	**Site**	**Trap**	**Species**	**Sex**	**Age**	**Width**	**Molt**	**Rlimb**	**#Limbs**	**Flap**	**Pleo**	**Ovig**	**Width**	**Length**	**Depth**	**Comment**
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
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18																			
19																			
20																			
21																			
22																			
23																			
24																			
25																			

SPECIES: _____ COUNT:

Sample Field Data Sheets: Cylinder Sampling-Physicals

											Entered by=
SIMCZ PHYSICALS											**Checked by=**
Date	**Locate**	**Habitat**	**Site**	**Trap**	**Temp**	**Salinity**	**DO**	**Depth**	**Tide**	**Time**	**Comment**

Field Supplies Checklist

YSI or similar unit to measure physicals

GPS unit (e.g., Garmin 76CX)

Data sheets on waterproof paper

Clipboards

Rulers

Pencils

Shallow tubs

Fish and Invertebrate ID books

Buckets

Volumetric bucket for vegetation

Long-handled dip nets

Two anchors with chain and line